

EXPERIMENTAL STUDY ON THE FLAME STABILITY AND THE NO_x EMISSION CHARACTERISTICS OF LOW CALORIFIC VALUE COAL DERIVED GAS FUEL USING FLAT FLAME BURNER

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ABSTRACT

Experimental studies are conducted to investigate the flame stability and the thermal/fuel NO_x formation characteristics of the low calorific value (LCV) coal derived gas fuel. Synthetic LCV fuel gas is produced by mixing carbon monoxide, hydrogen, nitrogen and ammonia on the basis that the thermal input of the syngas fuel into a burner is identical to that of natural gas. The syngas mixture is fed to and burnt with air on flat flame burner. With the variation of the equivalence ratio for specific syngas fuel, flame behaviors are observed to identify the flame instability due to blow-off or flashback and to define stable combustion range. Measurements of NO_x content in combustion gas are made for comparing thermal and fuel NO_x from the LCV syngas combustion with those of the natural gas one. In addition, the nitrogen dilution of the LCV syngas is preliminarily attempted as a NO_x reduction technique, and its effects on thermal and fuel NO_x production are discussed.

INTRODUCTION

Integrated Gasification Combined Cycle(IGCC) is emerging as a next-generation coal-based power plant because of its low fuel cost, competitive capital cost, high thermal efficiency and superior environmental performance. However, the gas fuel for gas turbine combustion in IGCC power plant is produced through oxygen-blown coal gasification and gas clean-up processes, so it is composed mainly of hydrogen, carbon monoxide and nitrogen that result in low calorific value of the fuel, 1/4-1/5 times smaller than the natural gas. In addition, due to high content of hydrogen in fuel, the LCV coal derived

gas shows very fast burning velocity, chemical reaction rate and high flame temperature[1]. As the consequence, flame instability can hardly be avoided in premixed combustion and NOx formation rate becomes much higher than in the natural gas case. For this reason, the most of combustion tests for LCV coal derived gas are conducted on the diffusion type burners incorporating with nitrogen and/or steam dilution for NOx control[2,3] while premix burner technology being at the first stage of development.

Therefore, for the efficient premixed combustor in IGCC power plant, fundamental characteristics of combustion stability and NOx emission of the LCV fuel gas need to be investigated and would be useful in providing engineering guidelines for future R&D of IGCC gas turbine combustor. In the present experimental study, coal gas burner system is constructed with the flexibility in varying various fuel composition and equivalence ratio conditions, and flame behavior and stability of the coal gas are observed and furthermore thermal and fuel NOx emission values are measured.

EXPERIMENTAL RESULTS AND DISCUSSIONS

As shown in Fig.1, experimental apparatus is composed of fuel/air feeding , premix burner and gas sampling/analysis systems. LCV fuel gas is simulated as synthetic gas that is produced by mixing carbon monoxide, hydrogen, nitrogen and ammonia. The syngas is premixed with air, fed to and burnt on flat flame burner with porous bronze water-cooled plate to produce uniform velocity distribution, and the burner does not employ the annular stream of inert gas as depicted in Fig.2. Flame behavior picture is recorded by using CCD/digital camera and image processing unit, and the NOx emission of sampled exhaust gas is analyzed.

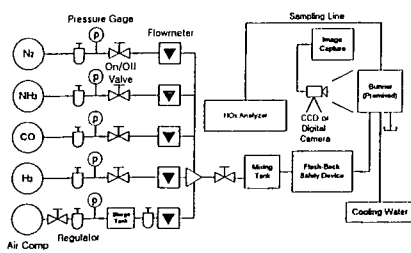


Fig.1 Schematic Diagram of Experimental Apparatus

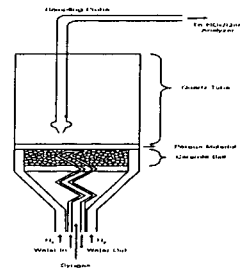


Fig.2 Flat Flame Burner

Before syngas combustion test, a reference experiment is carried out with natural gas fuel of the constant flow rate at 0.48 LPM. Flame of natural gas remains stable within the equivalence ratio range from 0.6 to 1.3, and its NOx emission level shows lower than 50 ppm. Syngas fuel is produced by mixing carbon monoxide and hydrogen to match the composition of actual coal gas fuel derived from oxygen blown gasifier, CO: 70-90 % and H₂: 10-30% on volume basis. Fuel flow rate is determined on the basis

that the thermal input of the syngas fuel is identical to that of natural gas. In addition, the present study considers NH_3 of 0-3000 ppm in syngas fuel to investigate the effect of NH_3 on fuel NO_x formation. Table 1 represents the fuel flow rates and the compositions of three different syngas fuels used in the present study.

Table 1 Composition and Flow Rate of Syngas Fuel

Syngas No.	$\text{CO}(\%)$	$\text{H}_2(\%)$	$\text{H}_2/\text{CO}(\%)$	Flow Rate(LPM)
1	91.0	9.0	9.9	1.64
2	82.0	18.0	34.1	1.66
3	70.0	30.0	42.8	1.69

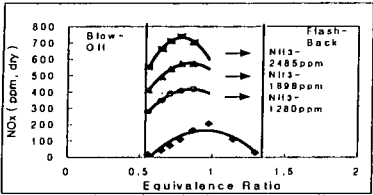


Fig.3(a) NO_x & Flame Stability of Syngas #1

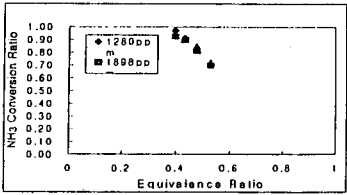


Fig.3(b) NH_3 Conversion Ratio of Syngas #1

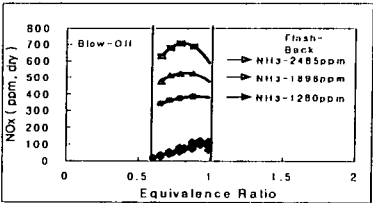


Fig.4(a) NO_x & Flame Stability of Syngas #2

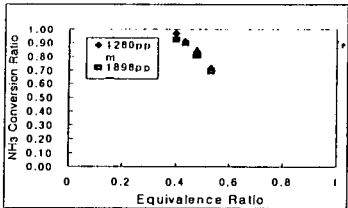


Fig.4(b) NH_3 Conversion Ratio of Syngas #2

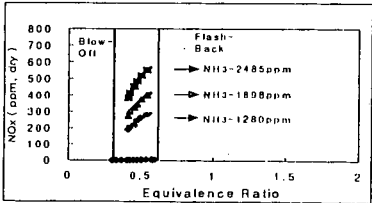


Fig.5(a) NO_x & Flame Stability of Syngas #3

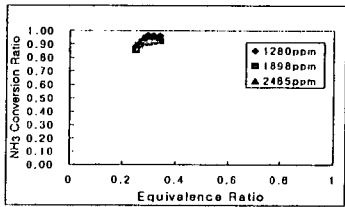


Fig.5(b) NH_3 Conversion Ratio of Syngas #3

Figs. 3(a), 4(a) and 5(a) illustrate the flame stability range and the NO_x emission of syngases with $H_2/CO = 9.9, 34.1$ and 42.8% respectively. They show that the flame stability range of syngas is shrunken into narrower range at higher H_2/CO ratio. These experimental results can be explained by that flashback occurs at lower equivalence ratio point due to higher burning velocity with the increase of H_2/CO ratio of syngas[4]. It is deduced from the measured results that if coal gas firing gas turbine combustor is designed with the same burner as the natural gas case, it can be operated only at narrow combustion condition range so careful design modification must be made on air distribution in combustor. As shown also in Figs. 3(a),4(a) and 5(a), thermal NO_x emission level is lowered for higher H_2/CO ratio syngas fuel with lower flame temperature at the stable combustion range. With the addition of NH_3 , NO_x emission is more produced by the order of 200-300 ppm, compared with the cases of NH_3 , over entire combustion range and its peak point is shifted to lower equivalence ratio compared with the thermal NO_x. Figs. 3(b), 4(b) and 5(b) present the variation of ammonia to NO_x conversion ratio with equivalence ratio at three syngas fuel conditions, and they show ammonia is more easily converted to NO_x at lower equivalence ratio condition[5,6].

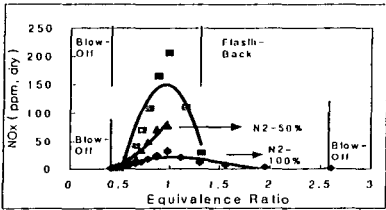


Fig.6 Effect of Nitrogen Dilution (Syngas#1)

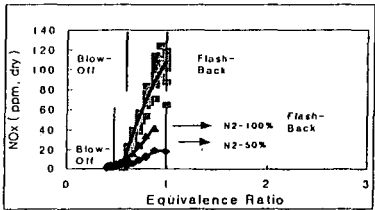


Fig.7 Effect of Nitrogen Dilution (Syngas#2)

The effects of nitrogen dilution on NO_x reduction are examined in Figs. 6 and 7. The present study employs nitrogen diluent that is blended with syngas fuel before entering burner, and its amount is considered as 50 or 100% of fuel flow rate on volume basis. Nitrogen dilution results in remarkable NO_x reduction as well as widening of flame stability range.

CONCLUSIONS

Flat flame burner tests are conducted for investigating flame stability and NO_x emission characteristics of three LCV syngas fuels with the same thermal input as the natural gas case. Flame stability range is shortened to narrower band of equivalence ratio and thermal NO_x is less produced when burning the syngas with higher H_2/CO ratio. The NH_3 content in fuel results in additional 200-300 ppm fuel NO_x formation as well as the shift of peak NO_x point to the lower equivalence ratio compared with the thermal NO_x case. The conversion ratio of NH_3 to NO_x ranges from 97 to 62% with the increase of equivalence

ratio. The effect of nitrogen dilution is very favorable both in reducing NOx emission and widening flame stability range.

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